Radiation Physics Note 67

A Survey of Radon in Fermilab Buildings

Rich Allen

August, 1987

Objective: In March 1987, Laboratory Services requested that the Safety Section conduct Radon surveys of Village residences. The initial effort involved ten samples taken in April. These samples were taken to determine whether any Village residents were exposed to Radon in quantities in excess of the EPA residential standard. The program was then expanded to identify geographical areas on-site with high Radon levels and attempt to determine factors associated with any elevated concentrations. A secondary objective was to measure Radon levels in tunnels and other work areas to estimate worst case occupational exposures.

Fermilab has a highly variable mix of structures ranging from 100+ year old frame farmhouses with flagstone basements to collision halls where the concrete is barely cured. Some residences were built on unpaved crawlspaces. Rundo (Ru79) has reported higher than normal Radon levels in Chicago area houses with unpaved crawlspaces. Other buildings have occupied basements. Some would be considered residential, while others are offices and laboratories.

Not all samples were taken in areas which would be considered representative breathing zones. Some were taken in locations where worst case Radon concentrations were suspected. In these cases, the lowest levels of buildings were chosen, with preference given to rooms with sumps. This follows EPA guidance (EPA86) governing screening of buildings for Radon rather than those procedures used to actually determine occupant dose.

Method: The charcoal canister adsorption method (Co76) was chosen for a number of reasons:

- The need for short-term testing due to limited access to operating areas
- Little interference from fast neutron exposure
- Availability of a local EPA listed laboratory
- Reasonable cost

The canisters were left exposed for four day periods, and then returned to the vendor.

Quality control and calibrations were handled by the vendor* who states a ±20% reproducibility.

Results and Discussion: The distribution of all measurements is shown in Figure 1, where we see that four of the locations (~10%) had results greater than the EPA residential standard of 4 pCi/L. None of these locations has a high occupancy factor. For the occupational environments, it is appropriate to convert the values to working levels. The worst case is the Site 68 basement where the 8.0 pCi/L concentration together with an occupancy factor of 10 hours per week gives 0.12 Working Level Months (WLM) per year. The occupational standard is 4 WLM/year.

The arithmetic average of all the data is 1.9 pCi/L. Cohen (Co86) states that such data ought to be log normally distributed, therefore the geometric mean of 1.4 x÷ 2.3 pCi/L is a more meaningful statistic. The data for this study suggests a log normal distribution (see Fig. 2) but there are too few data points to demonstrate good correlation.

The entire list of samples, including locations and other parameters is shown in Table 1. A number of general observations can be made. When two samples were taken in a building, the higher of the two results was usually the basement or crawlspace value. The ratio of basement to first floor measurements ranged from 1.0 to 7.8. Also, areas near sump pumps tended to have higher concentrations. The main ring tunnel locations were in good agreement with each other except for the E4 sump which was 4 times the others.

Other than the above, no good correlations could be drawn based on the other parameters which are alleged predictors of high Radon such as building materials, type of heating, time of year, age of structure and number of levels. Still, this is consistent with Cohen's study involving 453 homes nationwide. The geometric mean in that study was 1.03 x÷ 2.36 pCi/L. His conclusion was that the most significant factor in cases of high Radon concentration was the geographical location. In other words, if the ground under the structure doesn't contain much Radon, it doesn't matter how the house is built.

Conclusions: The results of this survey do not suggest a need for remedial action in any area. Based on 41 measurements geographically covering a large portion of the 27.5 km^2 site (see Fig. 3) it appears that the site is a normal Radon concentration area.

The only remaining question is that of variability based on weather conditions. The charcoal canister method is often criticized because of its "snapshot" approach to determining ambient concentrations. Although it is clearly not the best method for long-term studies, the standard deviation of results over the four month period was no worse than Cohen's 453 track etch detectors exposed for one year. A long-term study involving multiple samplers at one location is in progress.

*Amersham Corporation, Arlington Heights, IL

References

(Co76) Countess R.J., 1976, "Radon Flux Measurements with a Charcoal Canister," Health Phys. 31, 455.

(Co86) Cohen B.L., 1986, "A Survey of ^{222}Rn in U.S. Homes," Health Phys. 51, 175.

(Ru79) Rundo J., 1979, "Observation of High Concentrations of Radon in Certain Houses," Health Phys. 36, 729.

(EPA86) United States Environmental Protection Agency, 1986, "A Citizen's Guide to Radon," EPA OPA-86-004.

TABLE 1
RADON SAMPLING RESULTS

SAMP_ID	DS	BUILDING	ROOM	USE	TYPE	FOOTING	HEATING	PCI/L
870416RA01	LS	ASPEN EAST	HOUSING OFFICE	OFFICE	FRAME	FLAGST/BSMT	FORCED AIR	2.5
870416RA02	LS	ASPEN EAST	BASEMENT	OFFICE	FRAME	FLAGST/BSMT	FORCED AIR	2.4
870416RA03	LS	THE PAD	CRAWLSPACE	RESIDENCE	FRAME	CRAWLSPACE	FORCED AIR	1.7
870416RA04	LS	THE PAD	LOUNGE	RESIDENCE	FRAME	CRAWLSPACE	FORCED AIR	.8
870416RA05	LS	DORM 3	BASEMENT	RESIDENCE	FRAME	BASEMENT	FORCED AIR	4.5
870416RA06	LS	DORM 3	1ST FL LOUNGE	RESIDENCE	FRAME	BASEMENT	FORCED AIR	.7
870416RA07	LS	DORM 5	KITCHEN	RESIDENCE	FRAME	CRAWLSPACE	FORCED AIR	.4
870416RA08	LS	DORM 5	CRAWLSPACE	RESIDENCE	FRAME	CRAWLSPACE	FORCED AIR	.8
870416RA09	SS	14 SHABBONA	FRONT ROOM	LAB	FRAME	CRAWLSPACE	FORCED AIR	.5
870416RA10	LS	CHILDRENS CENTER	INFANT ROOM	DAYCARE	FRAME	CRAWLSPACE	FORCED AIR	.8
870508RA01	RD	ENCLOSURE M03	CABLE TRAV	BEAM LINE	CONCRETE	SLAB	?	1.5
870508RA02	RD	OLD MUON LAB NWA	U STORAGE ROOM	LAB	STEEL	SLAB	FORCED AIR	1.0
870508RA03	RD	OLD MUON LAB NWA	U STACK	LAB	STEEL	SLAB	FORCED AIR	.8
870508RA04	RD	NEW MUON LAB	BASEMENT/ELECTR	LAB	CONCRETE	BASEMENT	FORCED AIR	.9
870508RA05	BS	SITE 55 JANITORIAL	BASEMENT STORAG	OFFICE	FRAME	BASEMENT	WATER/AIR	2.7
870508RA06	LS	CHILDRENS CENTER	FRONT ROOM	DAYCARE	FRAME	CRAWLSPACE	FORCED AIR	1.1
870508RA07	TS	IB 4	CRYO TEST AREA	ASSEMBLY	STEEL	SLAB	FORCED AIR	.7
870522RA01	AD	MAIN RING	F45	BEAM LINE	CONCRETE	BASEMENT	N/A	2.0
870522RA02	AD	MAIN RING	E4-SUMP	BEAM LINE	CONCRETE	BASEMENT	N/A	8.8
870522RA03	AD	MAIN RING	E45	BEAM LINE	CONCRETE	BASEMENT	N/A	2.7
870522RA04	AD	MAIN RING	D0 COLLISION	BEAM LINE	CONCRETE	BASEMENT	N/A	2.4
870522RA05	AD	MAIN RING	C25	BEAM LINE	CONCRETE	BASEMENT	N/A	1.8
870522RA06	AD	MAIN RING	CDF DETECT. PIT	BEAM LINE	CONCRETE	BASEMENT	FORCED AIR	.7
870522RA07	AD	MAIN RING	A25	BEAM LINE	CONCRETE	BASEMENT	N/A	2.0
870522RA08	AD	PBAR A/D RING	AP-10 SUMP	BEAM LINE	CONCRETE	BASEMENT	N/A	.9
870522RA09	FL	WILSON HALL	SUB BASEMENT	OFFICE/LAB	CONCRETE	BASEMENT	FORCED AIR	.6
870605RA01	SS	SITE 68	BASEMENT	LAB	BRICK	BASEMENT	FORCED AIR	8.0
870622RA01	LS	6 SAUK CIRCLE	BASEMENT	RESIDENCE	FRAME	BASEMENT	FORCED AIR	3.6
870622RA02	LS	14 SAUK CIRCLE	BASEMENT	RESIDENCE	FRAME	DIRT/BSMT	FORCED AIR	1.1
870622RA03	LS	18 SAUK CIRCLE	LIVING ROOM	RESIDENCE	FRAME	BASEMENT	FORCED AIR	1.3
870622RA04	LS	SITE 58 (LEDERMAN)	BASEMENT	RESIDENCE	FRAME	FLAGST/BSMT	FORCED AIR	4.1
870622RA05	LS	SITE 58 (LEDERMAN)	LIBRARY	RESIDENCE	FRAME	FLAGST/BSMT	FORCED AIR	1.1
870622RA06	LS	SITE 29 (BJORKEN)	LAUNDRY	RESIDENCE	FRAME	BASEMENT	FORCED AIR	3.6
870622RA07	LS	SITE 29 (BJORKEN)	STUDY	RESIDENCE	FRAME	BASEMENT	FORCED AIR	1.9
870622RA08	BS	SITE 52 (SECURITY)	UTILITY	OFFICE	BRICK	BASEMENT	FORCED AIR	.9
870724RA01	BS	FIRE HOUSE	SLEEPING AREA	OFFICE/SLP	STEEL	SLAB	FORCED AIR	.4
870724RA02	RD	PE3/PS4	STAIRWELL	BEAM LINE	CONCRETE	SLAB	N/A	1.3
870724RA03	BS	SITE 50 T&M	FOYER	OFFICE	FRAME	LIMEST/BSMT	GAS/RADIATOR	.4
870724RA04	BS	SITE 50 T&M	BASEMENT	OFFICE	FRAME	LIMEST/BSMT	GAS/RADIATOR	3.1
870724RA05	SS	SITE 3	DRUM	STORAGE	FRAME	SLAB	N/A	.8
870724RA06	AD	LINAC	SUB BASEMENT	BEAM LINE	CONCRETE	SLAB	FORCED AIR	.9

UNLESS OTHERWISE NOTED, BASEMENTS ARE CONCRETE FLOOR AND WALL

Figure 1

Distribution of Radon Results

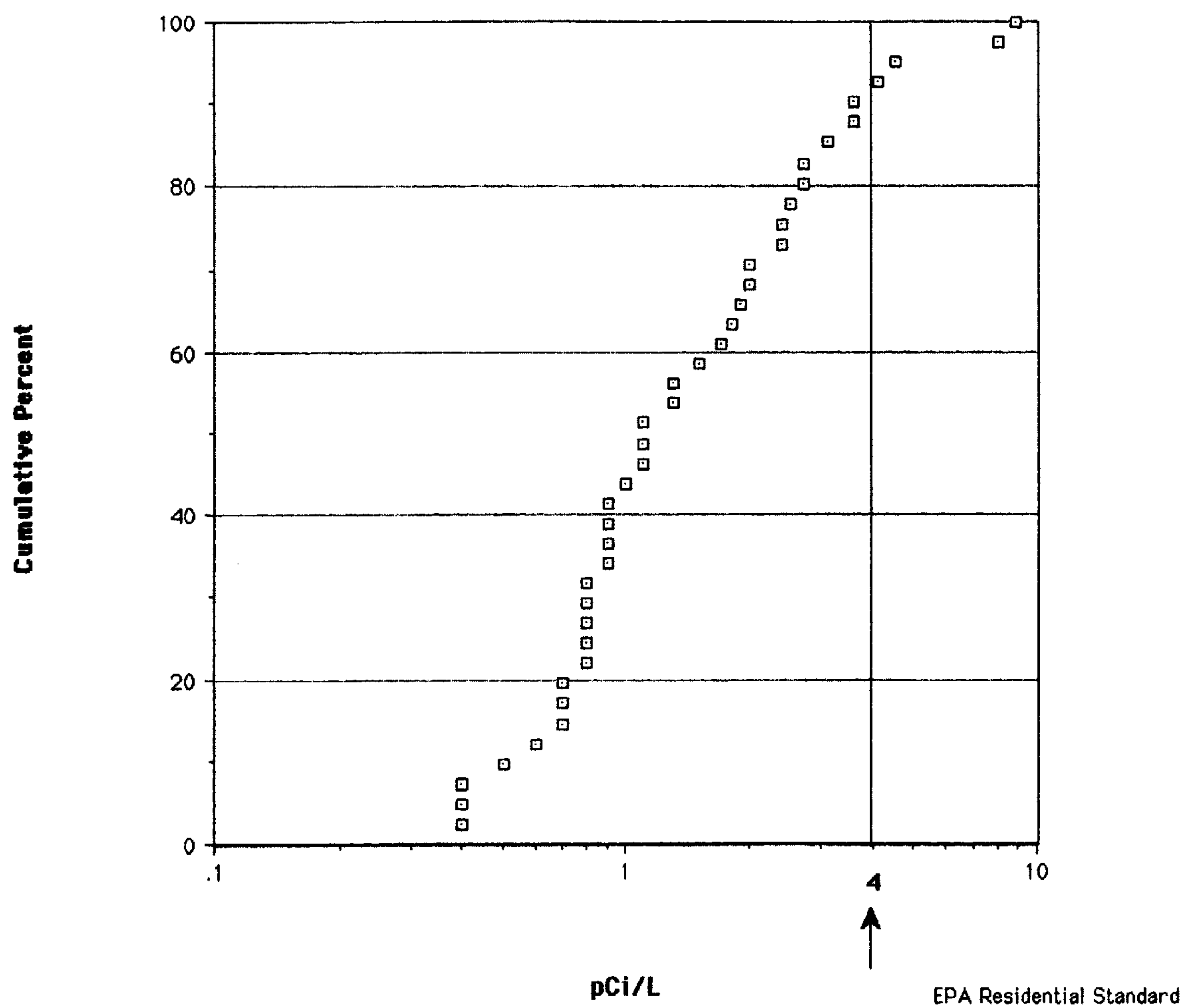

FIGURE 2

FREQUENCY DISTRIBUTION OF RADON RESULTS

```
PCI/L                       FREQUENCY

          0     2     4     6     8    10    12    14

        +------+------+------+------+------+------+------+
  .00   I==========
  .50   I================================================
 1.00   I====================
 1.50   I=============
 2.00   I=============
 2.50   I==========
 3.00   I===
 3.50   I======
 4.00   I===
 4.50   I===
 8.00   I===
 8.50   I===
```

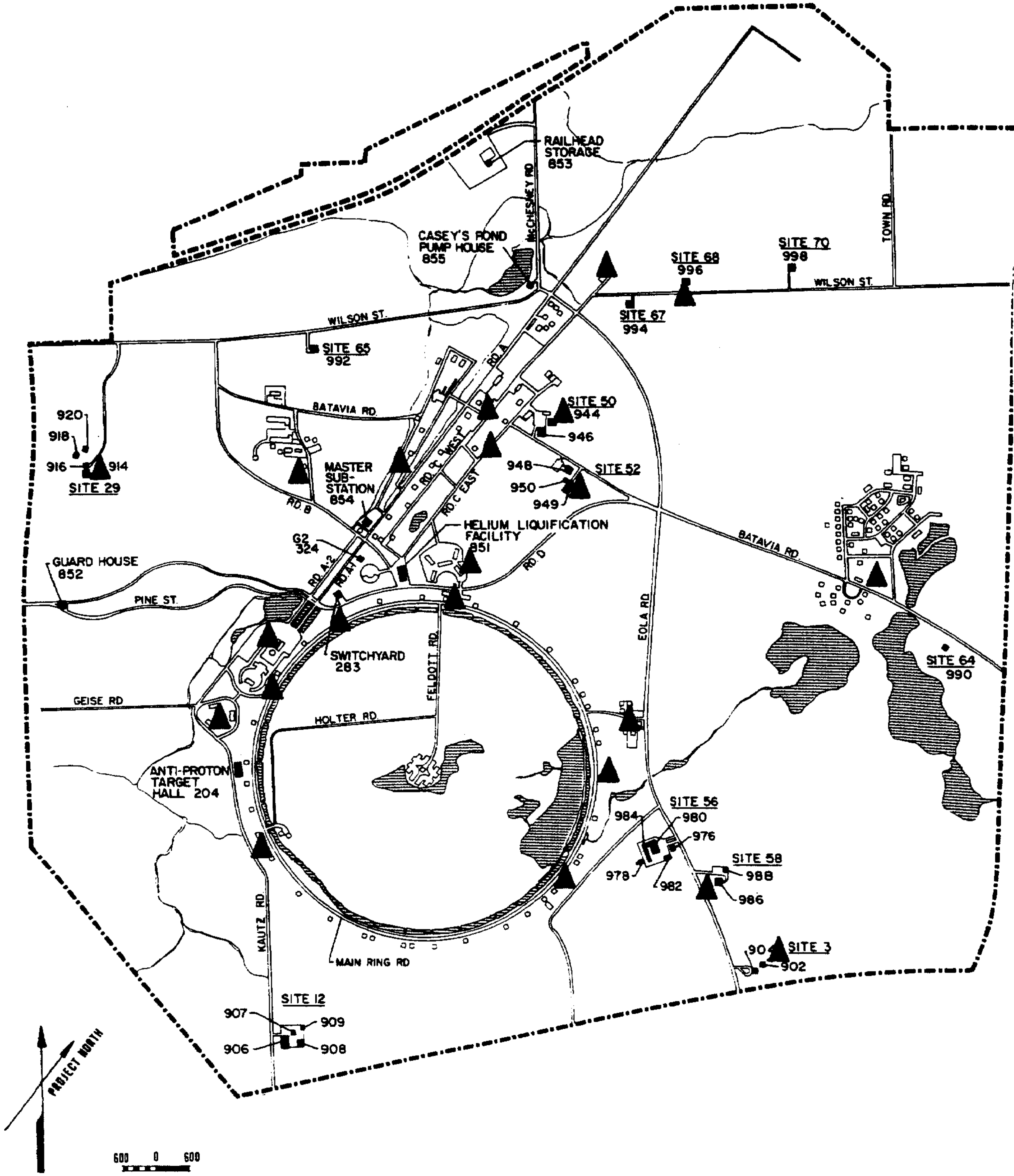

Figure 3 - Sites with one or more Radon samples taken ▲

Rich Allen

Radiation Physics Note #67

Addendum

April 1988

A criticism of R.P. Note #67 noted the possibility of variability of Radon concentrations based on weather conditions. Since the charcoal canister method only measures over a 4 day period, it may be possible to miss higher concentration spikes, or increased concentrations during colder months. For this reason, a long-term followup study was conducted at Dorm 3.

Between August 1987 and January 1988, seven additional canisters were placed in the same location in the Dorm 3 basement. Outdoor temperatures ranged from 32°C to -23°C during this period. Two canisters were in place during extremely wet periods in the fall. The results are shown in Table 2.

The geometric mean for the followup data is 2.2 x ÷ 1.1 pCi/L. There is no apparent variability in concentration based on temperature or humidity. In fact, the standard deviation of the data is smaller than that of the original study.

The data collected during the followup period provides evidence that the charcoal canister method is an acceptable screening method for typical Fermilab residences.

The data indicates that it is not likely that measurement results would have been significantly different had the study been conducted during some other season of year.

Table 2

Dorm 3 Long-Term Study

Sample	Canister	pCi/L
870824RA01	3567	1.5
870904RA01	3565	2.3
871029RA01	3548	1.8
871102RA01	3563	2.2
871106RA01	3562	2.6
871230RA01	3564	2.4
880108RA01	3549	2.1